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EFFECTS OF ADRENALIN OR INSULIN ON THE PERFORMANCE OF WORKING AND RESTING SUBJECTS

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by

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ABSTRACT

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The performance and physiological effects of adrenalin or insulin were studied in human subjects. After approximately eight hours of enforced work or rest, one group of nine subjects received insulin, and another group of nine subjects received adrenalin. The subjects in each drug group participated in both a working condition and a resting condition on separate occasions. Short-term memory, choice reaction time and steadiness tests were used to evaluate subject performance. Ten preinjection and seven postinjection sessions of performance testing were given. Postinjection performance decrements occurred on all three tests for all subjects, both working and resting, in the insulin group. Fewer decrements occurred in the adrenalin group. For the insulin group, postinjection decrements were most frequent in the working condition. However, for the adrenalin group, postinjection decrements were most frequent in the resting condition. Performance in the working condition of the insulin group had not recovered to preinjection levels three hours after injection, while recovery had occurred in all other conditions.

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INTRODUCTION

Comparative studies of human subjects in working and resting states are commonly conducted in physiology laboratories. Although many types of biomedical data may be obtained, performance data are seldom available for such studies. The present study was designed to evaluate the performance effects,

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as well as physiological effects, of insulin and adrenalin on human subjects in working and resting conditions. Even though the general symptoms resulting from injection of these drugs are well known, a systematic study of the performance effects was thought to be of value. A comparison of the frequency, latency and recovery of postinjection performance decrements in working and resting subjects was of major interest.

Three tests were selected for measurement of performance involving sensory, intellectual, and motor functions. Test durations were intended to be brief, but sufficient for collection of reliable data on subject performance. Tests of brief duration were selected so that complete test sessions could be given repeatedly over relatively short periods of time following drug injection, in order to detect any transitory effects of the drugs.

METHOD

Eighteen male subjects between the ages of 22 and 43 years participated in the experiment. The subjects had previously been given physical conditioning exercises over a three-month period. All subjects had served in both working and resting conditions in a previous study of the physiological and performance effects of prolonged work-stress.[1] The subjects were paid for their participation in the present study.

Each subject served in both a resting and working condition on separate test days. The subjects were assigned randomly to one of the two drug groups. Each subject received the same drug, either insulin or adrenalin, in both the working and resting conditions. Eight subjects in the adrenalin group and seven subjects in the insulin group completed the required schedule of testing. The data for three subjects who failed to complete the schedule are not included in this report.

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The subjects performed all their work by walking on a treadmill. The treadmill was adjusted in grade and speed, according to data collected prior to the experimental session, to impose a workload equivalent to one-third maximum oxygen uptake capacity of each subject, and thus equalize work output. These adjustments varied from 0 to 3 degrees inclination, and from 2.6 to 2.9 miles per hour in speed. The working subjects were walking on the treadmill during all performance testing. Resting subjects were confined in bed, in a semireclining position, and were required to remain awake at all times. During performance test sessions, the resting subject moved to a sitting position on the edge of the bed.

Subjects were allowed to consume only water after 6:00 P.M. on the day preceding a scheduled test, and were not allowed any food until the experimental period had ended.

A blood sample and blood pressure reading were taken at the beginning of the experimental period, and every 1 1/2 hours thereafter, for each working and resting subject. Blood samples from the working subject were obtained during a ten-minute nonactive period. Respiration rate, heart rate, and rectal temperature were evaluated continuously in both the working and resting conditions. Oxygen consumption determinations were made 45 minutes after the beginning of the experimental period, and at 1 1/2 hour intervals thereafter.

All subjects were tested in the resting condition, two subjects simultaneously, prior to being tested in the working condition. Figure 1 shows the test schedule and time of injection for the two resting subjects (A & B). Each experimental period began at approximately 7:30 A.M. In order to test each subject continuously for 1 1/4 hours following drug injection, one subject (A) was injected approximately 7 1/2 hours after the beginning of the experimental period, and the other subject (B) was injected after approximately 9 hours had elapsed. Four subjects in the adrenalin group and four subjects in the insulin group received the drug injection after 7 1/2 hours. Four subjects in the adrenalin group and three subjects in the insulin group were injected after 9 hours had elapsed. While only one subject per day was tested in the working condition, drug injection and performance testing corresponded to the schedule used for that subject in the resting condition.

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Insert Figure 1 about here
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The subjects were told that they would be injected with either adrenalin, insulin, or an unnamed solution which would cause no physiological or behavioral changes. This reference to a placebo was intended to minimize anticipatory effects of the injection. It was also stated that selection of the injection solution used for each subject would be entirely random for both resting and working conditions.

Blood samples were drawn from each subject immediately before drug injection. Subjects were then administered either regular insulin, in amounts of 0.05 units per kg. of body weight, or adrenalin, in amounts of 0.10 mg/kg. Insulin was injected intravenously, and adrenalin injections were intramuscular. Following drug administration, blood samples were obtained at 15-minute intervals for 1 1/2 hours. A final blood sample was taken three hours after drug injection.

The three performance tests were modifications of tests used in the previous treadmill study, and consisted of short-term memory, choice reaction time, and two-handed steadiness tests. Performance tests were given at 45-minute intervals for a total of 10 preinjection test sessions. Each session of performance testing required approximately nine minutes for completion. Following drug injection, performance testing was continuous for 1 1/4 hours, except when blood samples were being obtained. Two final sessions of performance testing were given approximately 2 1/2 and 3 1/4 hours after drug administration, for a total of 7 postinjection test sessions.

In the short-term memory test, a series of visual signals was projected on a one-plane alphanumeric display (Industrial Electronic Engineers, Inc., Series 10,000). The signals were three filled circles of white light, each of a different size, (0.3, 0.9, and 1.5 cm. in diameter). The signals were displayed singly, in random order, with a signal duration of 0.2 second, and a 1.0 second intersignal interval. The subject was required to monitor the visual display, and to maintain an independent count of the frequency of occurrence for each of the three circle sizes. A response was required when any circle of a given size had been displayed three times. The subject responded by depressing the appropriate button on a hand-held grip. While making a response, the subject was required to maintain the frequency of occurrence of the two other circle sizes. Following a response, counting was resumed for all circle sizes. The test consisted of 45 signals of each type, and required 15 responses to each of the three circle sizes. The measures recorded were the number of correct responses, the number of positive errors (too many signals included between responses), and the number of negative errors (too few signals included between responses). The duration of the short-term memory test was 162 seconds in each test session.

Choice reaction time was assessed by presentation of a series of visual signals on an alphanumeric display. The test consisted of 20 signals, 10 plus (+) and 10 minus (-) signals, presented in a random sequence. The duration of each signal was 0.2 second, with an intersignal interval randomized from 1.8 to 5.8 seconds, in 1.0 second increments. The subject responded by depressing a thumb-button on a hand-held grip. The plus signal required a right-hand response, and the minus signal required a left-hand response. The measures recorded were the total response time for each hand to the nearest hundredth of a second, the number of incorrect responses, and the number of signals missed in each test session. The choice reaction-time test required 80 seconds in each test session.

The two-handed steadiness test required the working subject to hold a 0.3 cm. diameter stylus, one in each hand, within rings of 3.8 cm. inside diameter. The rings for the resting subject measured 1.6 cm. inside diameter. Rings of smaller diameter were necessary for sensitive measurement in the resting condition because the reduction in body motion, as compared to the working condition, decreased the range of expected steadiness deviations. The subjects attempted to keep each stylus from contacting the inside of the corresponding ring, during a 180-second test period. The scores recorded were the total contact time, and number of contacts for each hand.

Insert Figure 2 about here

Figure 2 illustrates the display and response panel, with a working subject responding to the choice reaction-time test. The resting subject's display and response panel was identical to the working subject's panel, except for the difference in diameter of the steadiness rings. Resting subjects were tested in a room adjacent to the treadmill room, and were separated from each other by a screen. The experimenter's console was located in the room with the resting subjects.

The three performance tests were always given in the same sequence on each test session. Short-term memory was the first test, followed, in order, by choice reaction time and the stadiness test. The tests were programmed by a paper tape reader. Five program tapes were used throughout the experimental period, and were used in the same sequence on test sessions 1-5, 6-10, and 11-15. Tapes 1 and 2 were repeated for sessions 16 and 17.

The first test session was considered to be a training session for all subjects. Only test sessions 2-17 were included in the data analysis.

RESULTS

The data were analyzed separately for each subject to determine post-injection drug effects on individual subjects, in addition to group effects. Preinjection data (sessions 2-10) were used as a baseline for comparison with postinjection performance (sessions 11-17). Each subject's postinjection performance was classified as being improved, not changed, or degraded on a given test when compared with the corresponding baseline performance. The criterion for postinjection decrement was a greater degradation in performance on at least one postinjection session than had been recorded on any preinjection session. Postinjection decrements were, in most cases, large deviations from preinjection performance levels. Postinjection performance tending toward decrement or improvement, but not exceeding the range of preinjection scores, was classified as showing no change. Postinjection performance was described as improved when increments exceeded the range of preinjection scores.

Most baseline data were relatively stable for both the insulin and adrenalin groups, with performance tending neither to improve nor degrade over sessions 2-10. In the adrenalin group - - working condition, performance in five of eight subjects appeared to degrade (3 subjects showed no change) during the baseline period on the short-term memory test only. In all other conditions, for all tests, no more than two subjects tended to show degradation in pre-injection performance.

Insert Table I about here

Table I shows postinjection performance of individual subjects on the short-term memory test. All subjects in the insulin group had postinjection decrement in percentage of correct responses, in both the working and resting conditions. All subjects in the adrenalin group showed postinjection decrement in the resting condition, but only four of the eight subjects showed decrement in the working condition. Most maximum decrements occurred about 5 minutes after injection (on session 11) in the adrenalin-resting condition. Maximum decrements in the insulin group were most frequent approximately 20 minutes after injection (on session 12) for the working subjects, and about 35 minutes after injection (on session 13) for the resting subjects. Performance decrements tended to recover to preinjection levels by session 17 under all conditions. Short-term memory decrements in percentage of correct responses were, in nearly all cases, the result of an increase in positive error (too many signals included between responses).

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Insert Table II about here

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Postinjection performance on the choice reaction-time test is shown in Table II. In the insulin group, all working subjects, and six of seven resting subjects had postinjection decrement in choice reaction time. Maximum decrements tended to occur sooner after injection in the working condition than in the resting condition. Performance had recovered by session 17 for most resting subjects, but performance of three subjects failed to recover in the working condition. Both working and resting subjects in the insulin group also failed more often to respond to reaction time signals following drug injection, as compared to their preinjection performance. It is interesting to note that one subject in the resting condition showed a postinjection improvement in mean reaction time, but missed more signals in the postinjection period (6 signals missed on session 13, compared to a preinjection average of less than one missed signal per test session) than were missed by any other subject in the study. Most subjects in the adrenalin group did not show postinjection performance changes in mean reaction time, or in number of signals missed, in either the working or resting conditions. No postinjection changes in number of incorrect responses (anticipatory response to a reaction time signal and/or response on an inappropriate thumb-button) occurred in either the insulin or adrenalin groups.

Insert Table III about here

Table III shows postinjection performance on the two-handed steadiness test. All subjects in the insulin group had postinjection decrements in steadiness during both work and rest. Most subjects showed maximum increase in stylus contacts on session 12 (approximately 25 minutes after injection) in the working condition, and performance of four subjects failed to recover to preinjection levels by session 17. Maximum decrement occurred after session 12 in the resting condition, and performance recovered in six of the seven subjects. Most subjects in the adrenalin group did not show postinjection decrement in steadiness during work, but decrements did occur, mainly on sessions 11 and 12, in the resting condition. These decrements tended to recover by session 17. An analysis of the data for total contact time yielded essentially the same results as the analysis for number of contacts.

A tabulation was made of the number of subjects showing decrement at each test session. The results of this tabulation were consistent for all tests, and showed the largest number of postinjection decrements in the insulin group - - working condition. A smaller number of decrements was recorded in the insulin group - - resting condition, followed by a further reduction in frequency for the adrenalin group - - resting condition. The smallest number of postinjection decrements occurred in the adrenalin group - - working condition.

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Insert Figures 3, 4 and 5 about here

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In Figures 3, 4,and 5, each data point is an average of the performance of seven subjects for the insulin group, or eight subjects for the adrenalin group. Figure 3 shows mean performance (percentage incorrect) for the two drug groups on the short-term memory test. Mean performance (response latency) on the choice reaction-time test is illustrated in Figure 4, and mean performance (number of contacts) on the two-handed steadiness test shown in Figure 5. It is evident in Figures 3, 4,and 5, that postinjection decrements in the insulin group occurred in both working and resting conditions on all three tests. Maximum decrement in the working condition consistently occurred one test session earlier (approximately fifteen minutes) than in the resting condition. Performance in the working condition did not return to preinjection levels in two tests (choice reaction time and steadiness). In the resting condition, performance recovered on all tests by session 17. Postinjection decrements in the adrenalin group occurred only in the resting condition. Performance in the working condition was essentially unchanged following drug injection. In the resting condition, choice reaction time was unchanged, but a large decrement in short-term memory occurred on session 11, and a small decrement in steadiness developed on sessions 12 and 13. Performance recovered on both tests by session 14.

DISCUSSION

It was expected that the amounts of insulin and adrenalin used would be sufficient to cause performance decrements to occur in both drug groups. This expectation was confirmed. A greater number of postinjection decrements occurred in the insulin group than in the adrenalin group. Since it was not possible to equate the insulin and adrenalin dosages, the statement that insulin has a greater detrimental effect on performance than adrenalin is not warranted, except within the context of the dosages used in this study.

All subjects had been fasting for approximately 21 hours, and working subjects had been walking for either 7 1/2 or 9 hours, preceding the drug injection. It was predicted that working subjects would have severely depleted their glycogen reserves by the time of injection. A primary result of insulin injection, in both working and resting conditions, was expected to be a large decrease in subjects' blood glucose levels, with consequent symptoms of increased tremor, sweating, etc. Following injection, blood glucose could be restored more rapidly to preinjection levels in the resting condition, because larger glycogen reserves would be available, and blood glucose would not be utilized as rapidly as in the working condition. Therefore, reactions following insulin injection were expected to be much stronger and more persistent in the working subjects than would be the case for the same subjects in the resting condition. This explanation may account for the greater frequency and persistence of postinjection performance decrements in the working condition, as compared to the resting condition, for the insulin group.

The amount of adrenalin injected into each subject was expected to increase the blood glucose level, heart rate, and blood pressure. Development of drug symptoms (increased tremor, subjective feelings of anxiety, etc.) in the adrenalin group would be more likely to result from increase in heart rate and blood pressure, rather than the increase in blood glucose levels. Following injection, a greater percentage increase in heart rate and blood pressure was expected in resting rather than working subjects, because working subjects already had high heart rate and blood pressure prior to injection. Consequently, a greater percentage of postinjection performance effects could be expected to occur in the resting condition. All resting subjects in the adrenalin group did have some postinjection performance decrement, but few decrements were recorded in the working condition.

Performance decrements resulting from drug injection could be expected to reach a maximum sooner after injection in the working condition, rather than resting condition, primarily because of increased blood pressure and heart rate in the working subjects. Subjects in the insulin group did consistently show maximum decrement more rapidly in the working condition. For the adrenalin group, postinjection decrements were so infrequent in the working condition that a similar time comparison of working and resting decrements could not be made.

Maximum performance decrements (and observable symptoms) occurred in the resting condition much more rapidly after adrenalin injection, than after insulin injection. This happened despite the fact that insulin was given intravenously, while adrenalin was given intramuscularly. A possible explanation for the earlier development of adrenalin decrements is the probability that adrenalin effects were mainly caused by direct action of the drug on the heart and blood vessels. However, decrements following insulin injection would most likely result from a more indirect action and would develop, with some delay, after blood glucose levels had been lowered.

A detailed analysis and discussion of the biomedical data appears in a separate report.[2]

To conclude, the results of this study may be summarized in the following statements:

1. A greater number of postinjection performance decrements occurred in the insulin group than in the adrenalin group.
2. For the insulin group, postinjection decrements were most frequent in the working condition. For the adrenalin group, postinjection decrements were most frequent in the resting condition.
3. Following drug injection, the most rapid appearance of maximum decrement occurred in the adrenalin group - - resting condition. A greater delay was present in the insulin group, with maximum decrements appearing earlier in the working condition than in the resting condition. The few decrements in the adrenalin group - - working condition, occurred at irregular time intervals after injection.
4. Postinjection performance decrements did not recover to preinjection levels in the insulin group - - working condition, while recovery from decrement did occur in the other conditions.

REFERENCES

1. Young, D. R., Pelligra, R., and Adachi, R. R.: Serum glucose and free fatty acids in man during prolonged exercise. Submitted to Am. J. Physiol., February, 1965.

2. Pelligra, R., Young D. R., Adachi, R. R., Brooksby, G. A., and Debro, J. R.: Effects of insulin and adrenalin on blood glucose and non-esterfied fatty acids in normal fasting humans during prolonged work. Submitted to J. appl. Physiol., April, 1965.

TABLE I. DRUG STUDY

POSTINJECTION PERFORMANCE ON SHORT-TERM MEMORY TEST – NUMBER OF SUBJECTS WITH DECREMENT IN PERCENTAGE OF CORRECT RESPONSES

GROUP	CONDITION	POSTINJECTION PERFORMANCE			MAXIMUM DECREMENT IN PERFORMANCE ON SESSION							PERFORMANCE RECOVERY BY SESSION 17	NON-RECOVERY
		IMPROVEMENT	NO CHANGE	DECREMENT	11	12	13	14	15	16	17		
INSULIN (7 SUBJECTS)	WORK	0	0	7	1	4		1		1		5	2
	REST	0	0	7		2	4	1				6	1
ADRENALIN (8 SUBJECTS)	WORK	2	2	4	1			1	1		1	3	1
	REST	0	0	8	7	1						7	1

TABLE II. DRUG STUDY

POSTINJECTION PERFORMANCE ON CHOICE REACTION TIME TEST–
NUMBER OF SUBJECTS WITH DECREMENT IN MEAN REACTION TIME

GROUP	CONDITION	POSTINJECTION PERFORMANCE			MAXIMUM DECREMENT IN PERFORMANCE ON SESSION							PERFORMANCE RECOVERY BY SESSION 17	NON-RECOVERY
		IMPROVEMENT	NO CHANGE	DECREMENT	11	12	13	14	15	16	17		
INSULIN (7 SUBJECTS)	WORK	0	0	7	1	3			1	2		4	3
	REST	1	0	6		2	1	1	1	1		5	1
ADRENALIN (8 SUBJECTS)	WORK	0	6	2			1				1	1	1
	REST	1	5	2	1						1	1	1

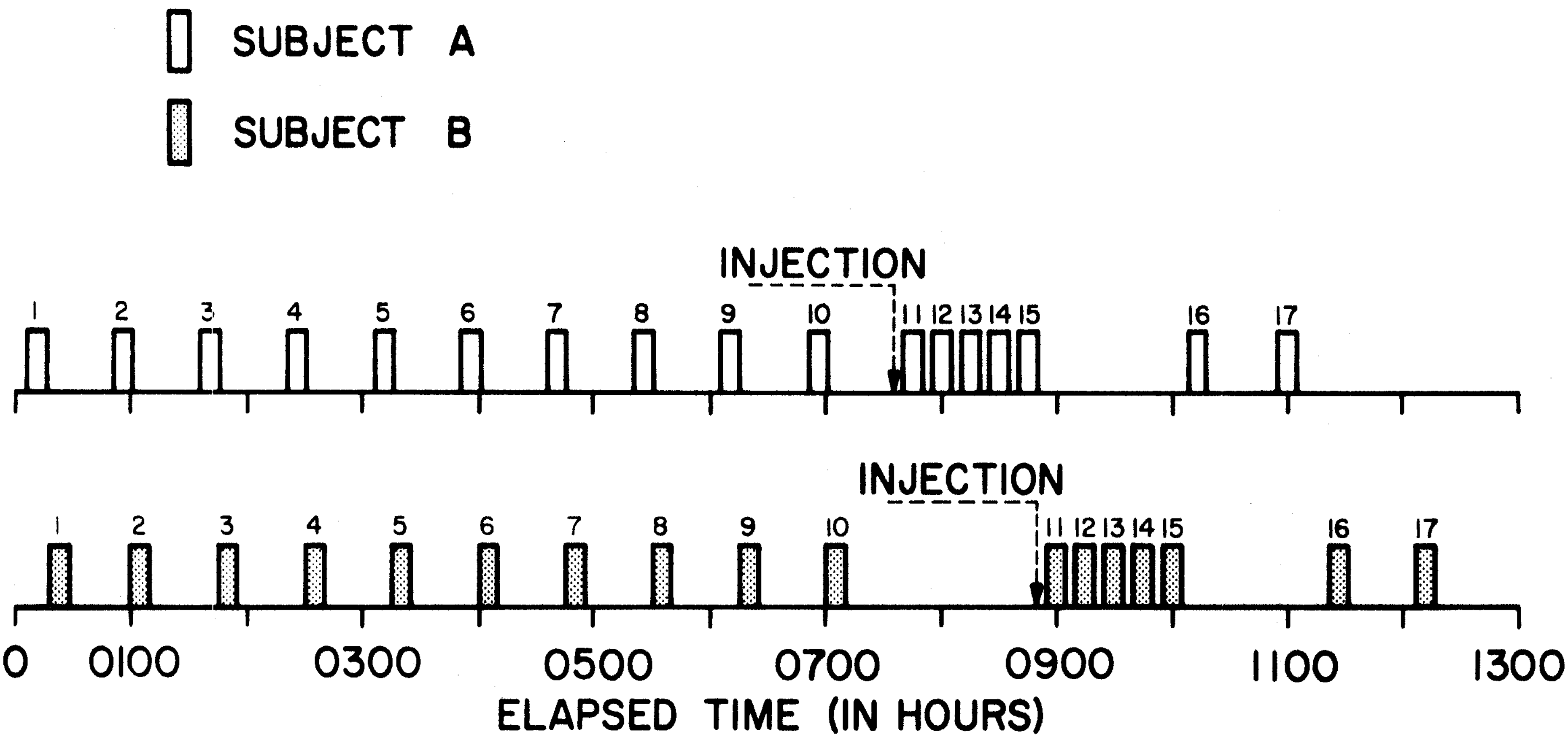
TABLE III. DRUG STUDY

POSTINJECTION PERFORMANCE ON STEADINESS TEST - NUMBER OF SUBJECTS WITH DECREMENT (INCREASE IN CONTACTS) IN STEADINESS

GROUP	CONDITION	POSTINJECTION PERFORMANCE			MAXIMUM DECREMENT IN PERFORMANCE ON SESSION							PERFORMANCE RECOVERY BY SESSION 17	NON-RECOVERY
		IMPROVEMENT	NO CHANGE	DECREMENT	11	12	13	14	15	16	17		
INSULIN (7 SUBJECTS)	WORK	0	0	7		5	1	1				3	4
	REST	0	0	7	1		2	2	1	1		6	1
ADRENALIN (8 SUBJECTS)	WORK	1	5	2	1						1	1	1
	REST	0	2	6	2	3	1					4	2

FIGURE 1. DRUG STUDY

PERFORMANCE TEST SCHEDULE FOR RESTING SUBJECTS
(NUMBERS REFER TO TEST SESSIONS)



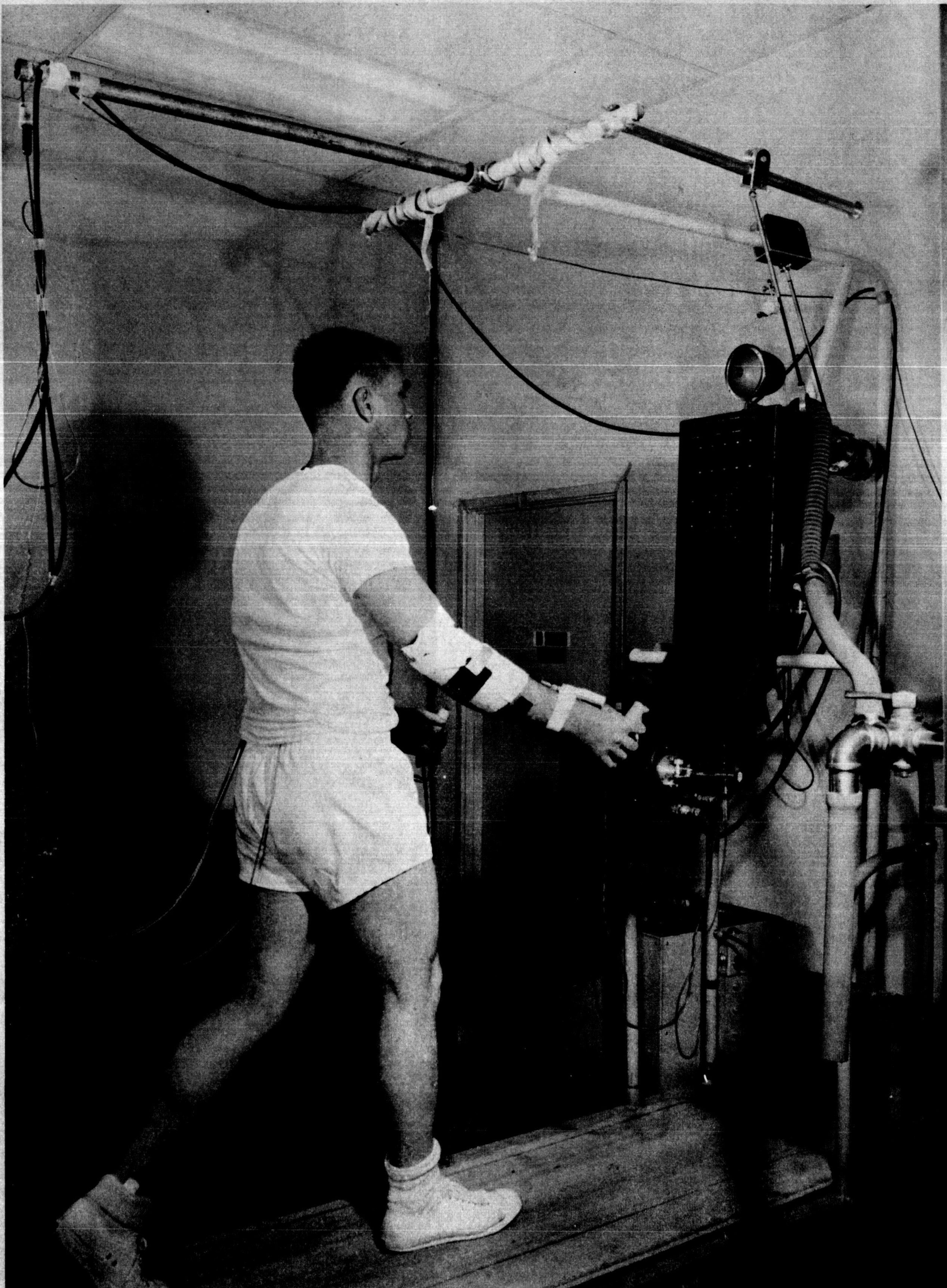


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FIGURE 2. - WORKING SUBJECT RESPONDING TO CHOICE REACTION TIME TEST.

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FIGURE 8. DRUG STUDY

RESULTS OF SHORT-TERM MEMORY TEST

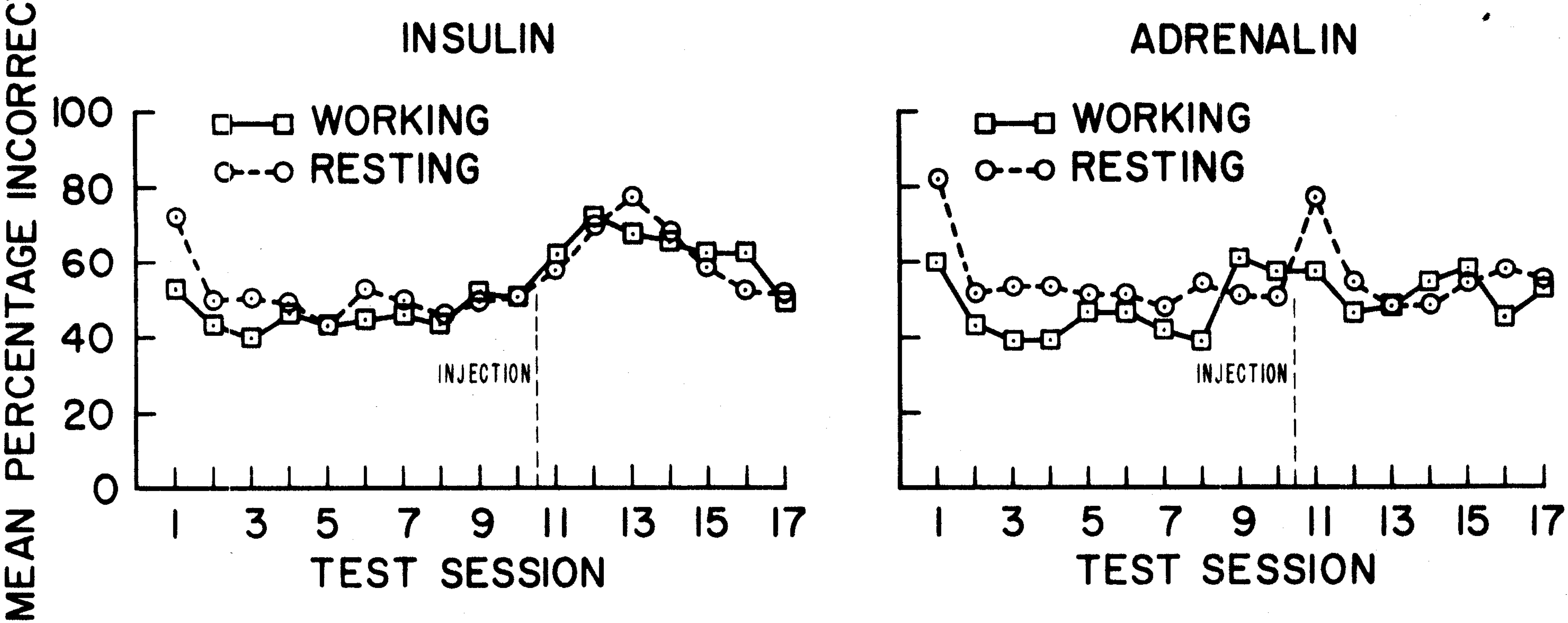

FIGURE 4. DRUG STUDY

RESULTS OF CHOICE REACTION TIME TEST

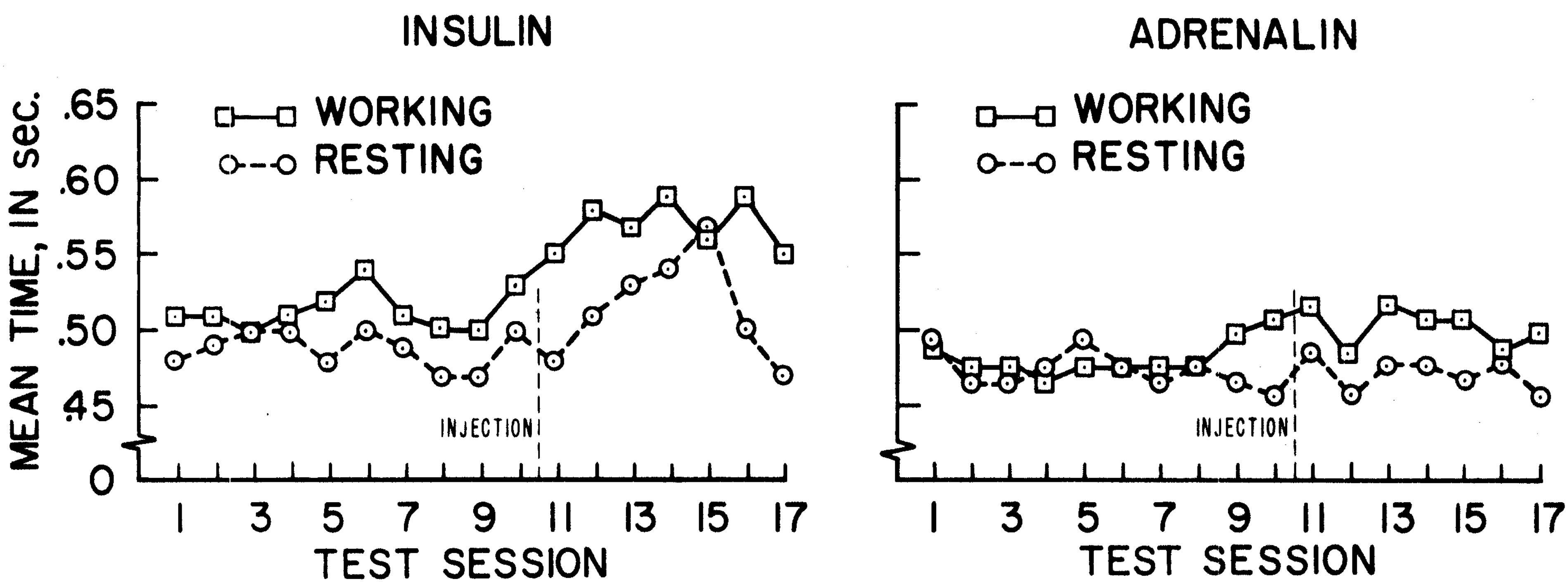

FIGURE 5. DRUG STUDY
RESULTS OF STEADINESS TEST